Injury Epidemiology in Professional Ballet: A Five-Season Prospective Study of 1596 Medical Attention Injuries and 543 Time-Loss Injuries

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ABSTRACT

Objectives To describe the incidence rate, severity, burden, and aetiology of medical attention and time-loss injuries across five consecutive seasons at a professional ballet company.

Methods Medical attention injuries, time-loss injuries, and dance exposure hours of 123 professional ballet dancers (female: n = 66, age: 28.0 ± 8.3 y; male: n = 57, age: 27.9 ± 8.5 y) were prospectively recorded between the 2015/16 and 2019/20 seasons.

Results The incidence rate (per 1000 h) of medical attention injury was 3.9 (95% CI: 3.3–4.4) for females and 3.1 (95% CI: 2.6–3.5) for males. The incidence rate (per 1000 h) of time-loss injury was 1.2 (95% CI: 1.0–1.5) for females and 1.1 (95% CI: 0.9–1.3) for males. First Soloists and Principals experienced between 2.0–2.2 additional medical attention injuries per 1000 hours and 0.9–1.1 additional time-loss injuries per 1000 hours compared to Apprentices ($p \leq .025$). Further, intra-season differences were observed in medical attention, but not time-loss, injury incidence rates with the highest incidence rates in early (August and September) and late (June) season months. Thirty-five percent of time-loss injuries resulted in over 28 days of modified dance training. A greater percentage of time-loss injuries were classified as overuse (female: 50%; male: 51%) compared to traumatic (female: 40%; male: 41%).

Conclusion This is the first study to report the incidence rate of medical attention and time-loss injuries in professional ballet dancers. Incidence rates differed across company ranks and months, which may inform targeted injury prevention strategies.

Key Words: Aetiology, Dance Medicine**,** Injury Surveillance

What are the new findings?

- This is the first study to document medical attention incidence rate in professional ballet and identify the burden placed on dance medicine and science teams through non-time-loss musculoskeletal complaints.
- Time-loss and medical attention incidence rates are highest in First Soloists and Principal dancers of a professional ballet company.
- Medical attention injury incidence rates are greater during the start and the end of the season compared to mid-season.
- The severity of time-loss injuries is high, with 35% of all injuries resulting in more than 28 days of modified dance.

How might it impact on clinical practice in the future?

- Company rank and month of the season offer opportunity to target context-specific risk factors in professional ballet.
- Lower extremity injuries may be addressed by injury-specific prevention strategies. These strategies may include targeting the ankle in females, and stress fractures of the foot and tibia in males.
- A high proportion of injuries were overuse in nature. Improved management of the rehearsal and performance schedule may mitigate the burden of these injuries.
- A common mechanism of injury was jumping and landing activities, which may warrant further attention from dance science and medicine practitioners.

INTRODUCTION

The probability of sustaining a musculoskeletal injury in professional ballet is high, with one article reporting an incidence proportion of 6.8 injuries per dancer over a season.[1] However, differences in time-loss injury are observed across professional ballet companies, with incidence proportions ranging from 1.8–6.8 injuries per dancer.[1–7] Similarly, differences in incidence rates are observed across studies, with values ranging from 0.6–4.4 injuries per 1000 hours of dance exposure.[1–3,5] The variation in incidence rates may reflect the use of contractual hours when calculating dance exposure (as opposed to individualised class, rehearsal, and performance schedules) or inconsistent injury definitions across studies.[3–7]

No research has described the incidence rate of medical attention injuries in professional ballet. The inclusion of medical attention injuries in epidemiology research has been recommended by Clarsen and Bahr,[8] and various consensus statements in sport,[9,10] as it provides a more comprehensive understanding of the medical burden within an organisation. Medical attention injuries, for example, impact performance outcomes in professional cricket.[11] Although performance outcomes in professional ballet are less tangible than sport, medical attention injury incidence rates may affect casting. Quantifying the incidence rate of medical attention injuries alongside time-loss injuries is therefore an important step towards effective medical management within professional ballet.[12]

Most injury epidemiology research in professional ballet is not reported in line with current methodological standards and lacks comprehensive contextual detail.[13] For example, atypical or no severity scales have been applied, there is inconsistent reporting of injury definitions, diagnoses, and tissue types, and few studies have reported differences in injury incidence rates and aetiology across contextual risk factors.[1–7] Specific injury risk factors, such as sex, company rank, and intra- and inter-season variation, have been identified in professional ballet.[14,15] However, only one study has reported statistical differences in injury incidence rates across sex and rank,[1] and although several studies have reported longitudinal injury incidence rates in professional ballet dancers,[2,3,5–7] none of these conduct statistical analyses.

This study aimed to investigate the sex, company rank, and intra- and inter-season differences in medical attention and time-loss injury incidence rates across five consecutive seasons at a professional ballet company. We also aimed to describe the severity, burden, and aetiology of medical attention and time-loss injuries.

METHODS

Study Design and Setting

A prospective cohort study design was employed to investigate medical attention and time-loss injuries in professional ballet dancers. Data were collected across five consecutive seasons at The Royal Ballet, commencing August 8th 2015 and ending March 15th 2020. The 2019/20 season ended prematurely due to the COVID-19 global pandemic. All scheduled dance events were completed within the Royal Opera House, London. All dance exposure and medical data were entered into standardised electronic forms (Smartabase version 6.5.11, Fusion Sport, Brisbane, Australia). Medical attention and time-loss injuries were evaluated and recorded by in-house Chartered Physiotherapists, typically within 24 hours of the onset. Dance exposure data were prospectively entered by the company Artistic Scheduling Manager. Injury diagnoses were categorised using version 10 of the Orchard Sports Injury Classification System (OSICS).[16] Data entered outside of each season were excluded from the analysis (e.g., tour, summer break). There was no patient or public involvement in the design, conduct, or reporting of this study.

Participants

Of 124 eligible elite professional dancers across the ranks of Apprentice, Artist, First Artist, Soloist, First Soloist, Principal, and Principal Character Artist, 123 were included in this analysis (female: 66, age: 28.0 ± 8.3 y; male: 57, age: 27.9 ± 8.5 y; Figure 1). Dancers who joined or left the company during the study period were included for the duration of their time in the company. Written informed consent was provided by 108 dancers. The remaining 16 were contacted, one of which declined consent, and 15 did not respond. A legitimate interest assessment to use the anonymised data for the present analysis was approved by the Data Controller of the Royal Opera House, in line with GDPR (2016) and the UK Data Protection Act (2018). Written support was provided by the Clinical Director of The Royal Ballet. Ethical approval was granted by St Mary's University Ethics Committee in accordance with the Declaration of Helsinki.

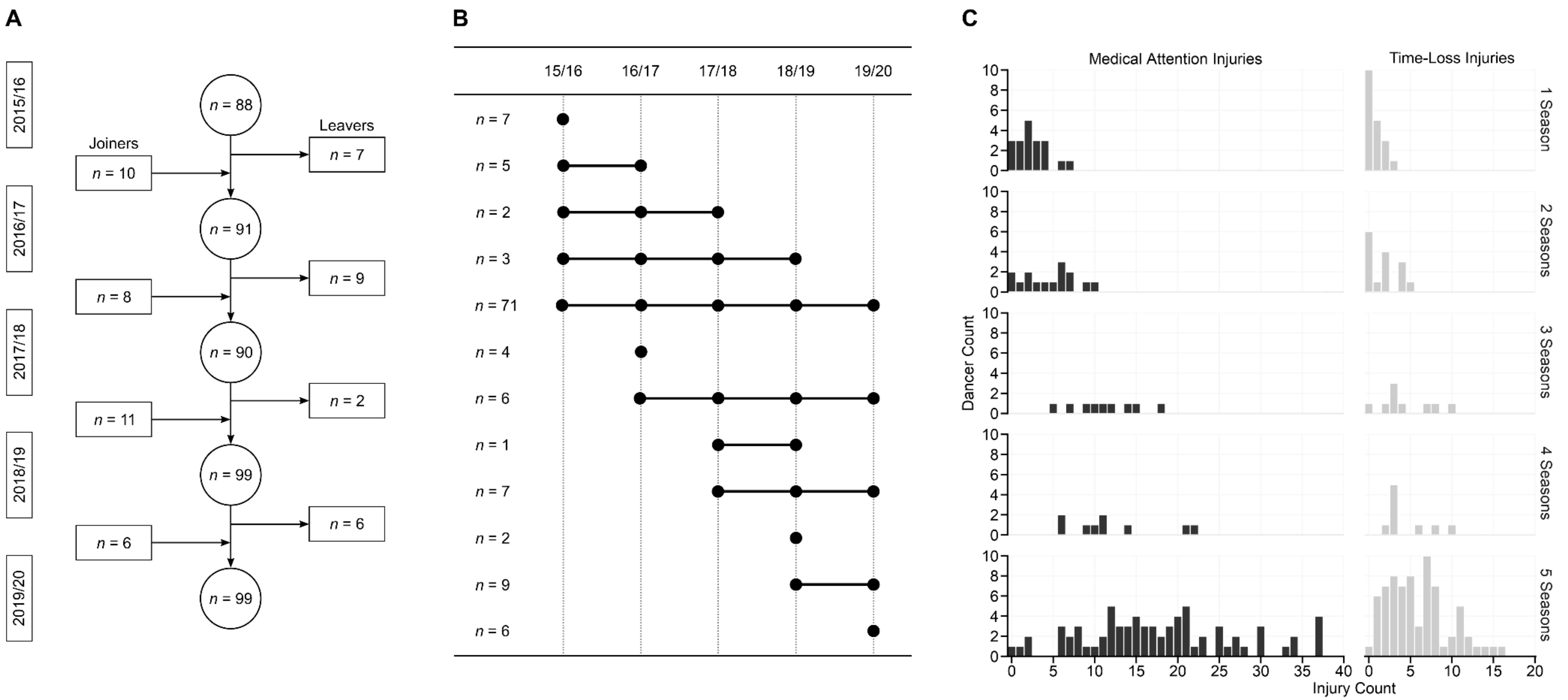

Figure 1 A) The number of participants joining, leaving, and present each season. B) The number of participants who were present across specific seasons. C) The count of injuries across participants who were involved in one, two, three, four, or five seasons.

Injury Definitions

Medical attention injuries were defined as "any musculoskeletal complaint that required medical attention from a physiotherapist".[8] Time-loss injuries were defined as "any injury that prevented a dancer from taking a full part in all dance-related activities that would normally be required of them for a period equal to or greater than 24 hours after the injury was sustained".[1] Time-loss injuries were closed on the date of their final appointment when no follow-up appointment occurred within 28 days. Prevalence was defined as the count of injured dancers divided by the count of included dancers each season. Incidence proportion was defined as the count of injuries divided by the count of included dancers each season. Severity was classified as either minor (1–7 days), moderate (8–28 days), or severe (>28 days).[17] Recurrent injury was defined as "any injury of the same location and type as the index injury, which occurred following a full return to all dance-related activities".[18] Overuse injuries were defined as "any medical incident that did not have a sudden onset from a discrete event".[19] The nature of injuries were categorised based on the physiotherapist's interpretation of the primary risk factor, where intrinsic was related to the characteristics of the individual and extrinsic was related to environmental factors.[2] The term "not classified" was applied when a physiotherapist was unable to distinguish the mechanism, activity, footwear, classification, occurrence, or nature of the injury.

Data Analysis

Dance Exposure

Individualised exposure hours for class, rehearsal, and performance were extracted from the online data management system and calculated for each dancer. Performance casts for each show were inspected manually and cross-referenced with updated casting sheets to account for cast changes. Following a new time-loss injury, prospectively scheduled dance events were removed to accurately calculate dance exposure. Individualised rehearsal and performance exposure hours were grouped by production length (i.e., stand-alone full-length ballets (≥ 90 minutes) or shorter productions that were staged together (< 90 minutes)), and by production type (i.e., new creations or existing works).

Medical Attention and Time-Loss Injury

The total medical attention injuries, time-loss injuries, and exposure hours were calculated for each unique dancer and grouped by sex, rank, month, season. The incidence rate (per 1000 h) of medical attention and time-loss injuries by production length, production type, anatomical region, and tissue type was calculated by dividing grouped injury count by grouped exposure time. Mean prevalence and incidence proportion of medical attention and time-loss injuries were calculated across the four complete seasons (2015/16–2018/19). Time-loss injury severity was calculated as median days lost, as severity data were not normally distributed. Time-loss injury severity was also calculated as the percentage of injuries classed as minor, moderate, and severe. Injury burden (days lost per 1000 h) and risk matrices (incidence rate × median severity) were calculated by anatomical region and tissue type. The number and percentage of medical attention and time-loss injuries by activity, mechanism, footwear, occurrence, classification, nature were calculated. For all values, 95% confidence intervals (CI) were calculated. Mechanism of injury fields were concatenated based on movement similarities (e.g., '*Plié*' and '*Relevé*' became *'Plié/relevé*'). The anatomical region and tissue type of injuries were classified using the OSICS diagnosis code.[13,16] There were five open injury records at the onset of the study. Three dancers were partaking in restricted rehearsals, and were therefore included in the study from the onset. Two were fully removed from normal rehearsal, but returned to rehearsal after 34 and 55 days; these dancers were included in the study following their return.

Statistical Analysis

A Poisson generalized linear mixed model was used to calculate incidence rates for all medical attention and time-loss injuries using the *lme4* package.[20] The output variable was the number of recorded medical attention and time-loss injuries offset by the log of dance exposure hours for each individual. Sex, rank, sex × rank interaction, month, and season were included as fixed factors. Dancer identity was included as a random factor to account for repeated observations over time. Main effects of the generalized linear mixed model were compared by applying an analysis of variance using the *car* package.[21] The estimated marginal means (EMM) for each fixed factor were extracted from the model, with 95% CI, and back-transformed to calculate incidence rate per 1000 hours using the *emmeans* package.[22] Post-hoc pairwise comparisons, with false discovery rate adjustment, were used to investigate statistically significant main effects.[22] Significance was set at $p \leq .025$ to account for two primary outcome measures. All data and statistical analysis were conducted using *R* (version 4.0.3, R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Dance Exposure

There were 20,762 unique scheduled dance events over 5 consecutive seasons. This resulted in 283,453 individual dancer events (class: 99,733; rehearsal: 152,588; performance: 31,132). Scheduled dance events represented a total of 417,693 hours of individual dance exposure (class: 115,772; rehearsal: 209,529; performance: 92,392).

Injuries

Table 1 outlines the number of dancers, medical attention injuries, and time-loss injuries over the five seasons. The count of injuries by dancer and number of seasons in the company is presented in Figure 1

Table 1 Number of dancers, medical attention injuries, and time-loss injuries across five consecutive seasons.

	2015/16			2016/17			2017/18			2018/19			2019/20		
	n	MA	TL	*n*	MA	TL	*n*	MA	TL	*n*	MA	TL	*n*	MA	TL
All	88	384	88	91	305	112	90	338	138	99	286	130	99	283	75
Female	48	228	53	50	180	60	49	183	75	52	171	70	53	163	42
App.	2	8	1	4	10	4	3	4	2	4	5	1	4	12	2
Artist	11	46	8	11	46	11	10	53	21	14	53	17	12	33	7
F. Artist	9	35	12	10	31	11	11	43	26	10	28	10	12	48	16
Soloist	11	62	21	9	27	10	8	30	7	4	11	3	5	15	3
F. Soloist	7	39	5	7	33	12	6	18	4	9	37	21	9	31	3
Principal	6	36	6	8	31	10	8	30	12	8	29	13	8	16	8
PCA	2	2	0	1	2	2	3	5	3	3	8	5	3	8	3
Male	40	156	35	41	125	52	41	155	63	47	115	60	46	120	33
App.	3	6	0	4	9	2	4	18	9	4	4	1	2	4	0
Artist	7	30	5	7	26	9	7	23	11	10	30	15	11	36	11
F. Artist	5	21	5	6	20	4	6	22	5	7	14	8	7	24	5
Soloist	8	27	7	7	21	13	7	39	14	7	26	15	8	15	4
F. Soloist	7	29	6	5	20	9	4	20	11	5	14	9	5	14	4
Principal	7	42	12	9	27	13	8	23	8	9	20	8	8	23	6
PCA	3	1	0	3	2	2	5	10	5	5	7	4	5	4	3

App., Apprentice; F. Artist, First Artist; F. Soloist, First Soloist; PCA, Principal Character Artist; MA, Medical Attention Injury; TL Time-Loss Injury

Incidence Rates by Sex and Company Rank

The incidence rates of medical attention and time-loss injuries can be found in Table 2. A significant main effect of company rank was observed on medical attention injury incidence rate (F_7 = 2209.1; $p < .001$). Post-hoc pairwise comparisons revealed that medical attention incidence rates were lower in Apprentices (2.5 per 1000 h; 95% CI: 1.9–3.2) than First Soloists (4.5 per 1000 h; 95% CI: 3.7–5.5; $p = .003$), and Principals (4.7 per 1000 h; 95% CI: 3.9–5.8; $p = .002$). No significant main effects of sex ($p = .031$) or sex × rank ($p = .659$) were observed on medical attention incidence rate.

A significant main effect of company rank was observed on time-loss injury incidence rate (F_7 = 1216.2; $p < .001$). Post-hoc pairwise comparisons revealed that Apprentices (0.6 per 1000 h; 95% CI: 0.4–1.0) demonstrated lower time-loss injury incidence rates than First Soloists (1.5 per 1000 h; 95% CI: 1.1–2.1; $p = .015$) and Principals (1.7 per 1000 h; 95% CI: 1.3–2.4; $p = .006$). No significant main effects of sex ($p = .496$) or sex × rank ($p = .205$) were observed on time-loss injury incidence rate.

Table 2 Estimated marginal mean incidence rate (per 1000 h), prevalence (% injured dancers), incidence proportion (injuries per dancer) of medical attention and time-loss injuries across five consecutive seasons (95% confidence intervals).

	Medical Attention Injury						**Time-Loss Injury**					
	Incidence Rate		**Prevalence***		**Incidence Proportion***		**Incidence Rate**		**Prevalence***		**Incidence Proportion***	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
All Ranks	3.9 (3.3–4.4)	3.1 (2.6–3.5)	91.5 (82.0–100.0)	88.4 (78.5–98.2)	3.8 (3.7–4.0)	3.3 (3.0–3.6)	1.2 (1.0–1.5)	1.1 (0.9–1.3)	70.3 (60.8–79.9)	61.4 (51.6–71.3)	1.3 (1.1–1.5)	1.2 (1–1.5)
App.	2.7 (1.9–3.8)	2.3 (1.6–3.3)	79.2 (57.6–100.0)	87.5 (56.7–100.0)	2.3 (2.0–2.6)	2.4 (1.4–3.4)	0.6 (0.3–1.3)	0.6 (0.3–1.1)	45.8 (24.2–67.4)	31.2 (0.4–62.1)	0.6 (0.3–0.9)	0.8 (0.0–1.8)
Artist	3.4 (2.8–4.2)	3.1 (2.5–3.9)	94.2 (79.2–100.0)	93.9 (70.7–100.0)	4.4 (3.8–4.9)	3.6 (3.2–4.0)	0.9 (0.6–1.3)	1.0 (0.7–1.5)	68.1 (53.2–83.1)	73.6 (50.3–96.8)	1.3 (0.7–1.8)	1.3 (0.9–1.6)
F. Artist	4.2 (3.4–5.3)	2.8 (2.1–3.7)	92.2 (73.9–100.0)	88.7 (77.0–100.0)	3.4 (2.8–4.0)	3.3 (3.1–3.5)	1.5 (1.1–2.2)	0.7 (0.4–1.1)	76.4 (58.1–94.7)	50.1 (38.4–61.8)	1.4 (0.8–2.1)	0.9 (0.7–1.1)
Soloist	4.1 (3.2–5.2)	3.2 (2.5–4.2)	85.1 (66.8–100.0)	90.2 (70.1–100.0)	3.8 (3.3–4.3)	3.9 (3.4–4.5)	1.4 (0.9–2.1)	1.3 (0.9–1.9)	68.7 (50.4–87.0)	66.5 (46.4–86.6)	1.2 (0.7–1.7)	1.7 (1.2–2.3)
F. Soloist	5.3 (4.1–6.9)	3.8 (2.8–5.2)	93.7 (72.9–100.0)	100.0 (88.1–100.0)	4.3 (3.6–5.1)	4.0 (3.2–4.7)	1.5 (0.9–2.2)	1.6 (1.0–2.6)	71.0 (50.3–91.8)	82.9 (71.0–94.7)	1.4 (0.6–2.2)	1.8 (1.0–2.6)
Principal	4.8 (3.5–6.4)	4.7 (3.6–6.3)	100.0 (91.6–100.0)	96.9 (87.3–100.0)	4.3 (4.0–4.6)	3.5 (3.1–3.9)	1.7 (1.1–2.6)	1.8 (1.2–2.8)	76.0 (67.6–84.5)	66.8 (57.2–76.4)	1.3 (1.1–1.6)	1.3 (0.9–1.6)
PCA	3.2 (1.8–5.5)	2.1 (1.3–3.5)	87.5 (46.4–100.0)	45.0 (18.1–71.9)	1.8 (1.0–2.7)	1.1 (0.7–1.5)	1.6 (0.7–3.6)	1.1 (0.5–2.1)	58.3 (17.2–99.4)	36.7 (9.7–63.6)	1.2 (0.3–2.0)	0.6 (0.2–1.0)

App., Apprentice; F. Artist, First Artist; F. Soloist, First Soloist; PCA, Principal Character Artist; MA, Medical Attention Injury; TL, Time-Loss Injury; * calculated based on four seasons of data due to the premature end of the 2019/20 season.

Intra- and Inter-Season Incidence Rates

A significant main effect of month ($F_{10} = 59.7$; $p < .001$) and season ($F_4 = 31.9$; $p < .001$) was observed on medical attention injury incidence rate (per 1000 h); post-hoc pairwise comparisons are illustrated in Figure 2. No main effects of month ($p = .029$) or season ($p = .042$) were observed on time-loss injury incidence rate.

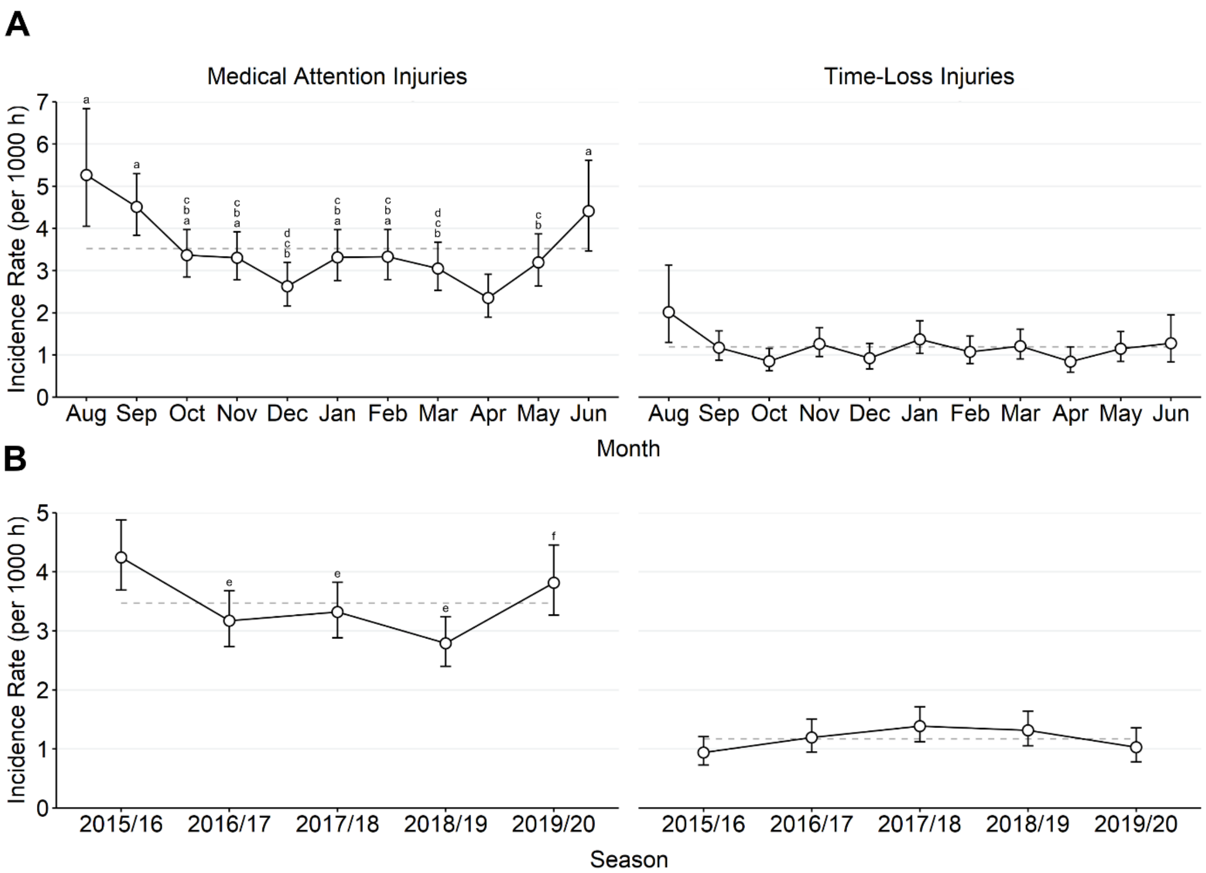

Figure 2 A) Intra-season medical attention and time-loss injury incidence rate with 95% CI. [a] Significantly different to April ($p < .025$); [b] Significantly different to August ($p < 0.025$); [c] Significantly different to September ($p < .025$); [d] Significantly different to June ($p < .025$). B) Inter-season medical attention and time-loss injury incidence rate with 95% CI. [e] Significantly different to the 2015/16 season ($p < .025$); [f] Significantly different to the 2018/19 season ($p < .025$).

Incidence Rates by Production Type

Medical attention and time-loss injury incidence rates were 6.0 (95% CI: 5.5–6.6) and 2.0 (95% CI: 1.7–2.3) per 1000 hours for mixed bills and 3.7 (95% CI: 3.4–4.0) and 1.2 (95% CI: 1.1–1.4) per 1000 hours for full-length productions, respectively. Medical attention and time-loss injury incidence rates were 4.2 (95% CI: 3.6–4.8) and 1.5 (95% CI: 1.2–1.9) per 1000 hours for new creations and 4.3 (95% CI: 4.0–4.6) and 1.4 (95% CI: 1.3–1.6) per 1000 hours for existing productions, respectively.

Prevalence and Incidence Proportion

Table 2 outlines the mean prevalence and incidence proportion of medical attention and time-loss injuries across the four complete seasons (2015/16–2018/19).

Severity, Burden, and Aetiology of Time-loss Injuries

Table 3 presents the median severity and percentage of time-loss injuries by severity scale. Figure 3 illustrates the time-loss injury burden by anatomical region and tissue type. The incidence rate, severity, and burden of time-loss injuries by anatomical region and tissue type are presented in Supplementary Table 1. Supplementary Table 2 outlines the percentage of medical attention and time-loss injuries by classification, occurrence, and nature. The percentage of medical attention and time-loss injuries by mechanism, activity, and footwear is provided in Supplementary Table 3.

Table 3 Median severity of time-loss injuries and percentage of time-loss injuries by severity scale (95% confidence intervals)

	Female	Male
Median Severity (days)		
All Ranks	14 (10–16)	14 (7–16)
App.	17 (2–123)	22 (10–39)
Artist	10 (3–16)	12 (6–31)
F. Artist	24 (11–30)	14 (3–18)
Soloist	9 (3–33)	12 (3–18)
F. Soloist	18 (8–25)	21 (8–41)
Principal	9 (4–16)	6 (2–27)
PCA	10 (1–14)	14 (6–25)
Severity Scale (%)		
Mild (1–7 days)	39.9 (24.7–55.1)	41.5 (26.5–56.5)
Moderate (8–28)	25.2 (8.2–42.1)	23.7 (6.5–40.8)
Severe (>28)	34.9 (19.1–50.7)	34.9 (19.0–50.7)

App., Apprentice; F. Artist, First Artist; F. Soloist, First Soloist; PCA, Principal Character Artist

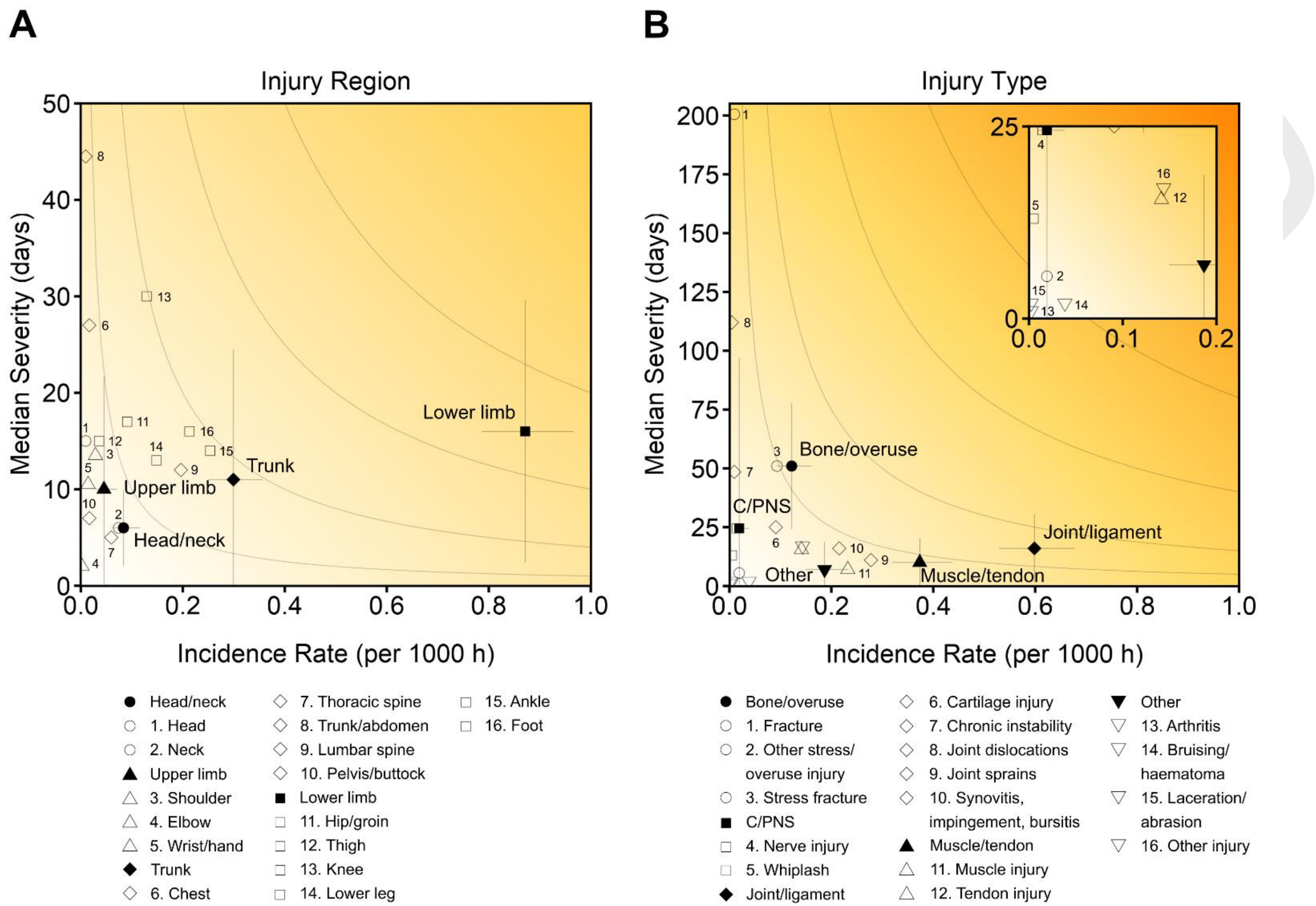

Figure 3 A) Time-loss injury burden (incidence rate × median severity) by anatomical region with 95% CI. B) Time-loss injury burden (incidence rate × median severity) by tissue type with 95% CI. The top right corner of plot B depicts a zoomed-in subsection of the main plot identifiable by the axis. It should be noted that the y-axis scale across plot A and B are not equal.

Supplementary Table 1 Number of injuries, incidence rate (injuries per 1000 h), severity (median days lost), and burden (days lost per 1000 h) of time-loss injuries by injury region and tissue type (95% confidence intervals).

	***n* injuries**		**Incidence Rates**		**Severity**		**Burden**	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
Head	2	2	0.01 (0.00–0.04)	0.01 (0.00–0.04)	15 (0–33)	15 (0–40)	0 (0–1)	0 (0–1)
Neck	17	14	0.08 (0.05–0.12)	0.07 (0.04–0.12)	4 (0–9)	6 (0–13)	1 (0–1)	1 (0–1)
Shoulder	3	9	0.01 (0.00–0.04)	0.05 (0.02–0.09)	7 (0–48)	17 (2–32)	0 (0–1)	1 (1–2)
Elbow	1	-	0.00 (0.00–0.03)	-	2 (0–0)	-	0 (0–0)	-
Wrist/hand	1	5	0.00 (0.00–0.03)	0.03 (0.01–0.06)	14 (0–0)	7 (0–33)	0 (0–0)	0 (0–1)
Chest	4	3	0.02 (0.01–0.05)	0.02 (0.00–0.05)	18 (0–106)	27 (0–76)	1 (0–2)	1 (0–2)
Thoracic spine	10	15	0.04 (0.02–0.08)	0.08 (0.05–0.13)	10 (0–24)	4 (0–32)	1 (0–2)	2 (1–3)
Trunk/abdomen	4	-	0.02 (0.01–0.05)	-	44 (0–101)	-	1 (0–3)	-
Lumbar spine	48	34	0.22 (0.16–0.29)	0.17 (0.12–0.24)	16 (2–31)	5 (0–37)	6 (5–9)	6 (4–9)
Joint sprains	5	5	0.02 (0.01–0.05)	0.03 (0.01–0.06)	39 (0–100)	6 (0–39)	1 (1–4)	1 (0–1)
Cartilage injury	11	5	0.05 (0.03–0.09)	0.03 (0.01–0.06)	20 (0–51)	27 (8–46)	2 (1–3)	1 (0–1)
Synovitis, impingement, bursitis	14	11	0.06 (0.04–0.11)	0.06 (0.03–0.10)	12 (3–21)	2 (0–32)	1 (1–2)	1 (1–2)
Muscle injury	10	8	0.04 (0.02–0.08)	0.04 (0.02–0.08)	12 (0–34)	2 (0–21)	1 (1–2)	1 (0–1)
Pelvis/buttock	6	1	0.03 (0.01–0.06)	0.01 (0.00–0.04)	9 (0–59)	1 (0–0)	1 (0–2)	0 (0–0)
Hip/groin	26	12	0.12 (0.08–0.17)	0.06 (0.03–0.11)	23 (0–56)	10 (0–24)	6 (4–8)	1 (1–2)
Synovitis, impingement, bursitis	8	4	0.04 (0.02–0.07)	0.02 (0.01–0.05)	27 (0–114)	15 (2–28)	2 (1–5)	0 (0–1)
Other injury	7	3	0.03 (0.01–0.07)	0.02 (0.00–0.05)	33 (0–92)	52 (21–83)	2 (1–4)	1 (0–2)
Thigh	5	10	0.02 (0.01–0.05)	0.05 (0.03–0.10)	6 (0–19)	16 (0–38)	0 (0–1)	1 (1–2)
Knee	25	29	0.11 (0.08–0.17)	0.15 (0.10–0.21)	21 (0–64)	32 (0–72)	7 (5–11)	9 (6–13)
Joint sprains	5	3	0.02 (0.01–0.05)	0.02 (0.00–0.05)	119 (0–256)	17 (0–308)	3 (1–6)	2 (1–8)
Tendon injury	2	12	0.01 (0.00–0.04)	0.06 (0.03–0.11)	80 (55–105)	25 (0–64)	1 (0–3)	3 (1–5)
Lower leg	32	30	0.14 (0.10–0.20)	0.15 (0.11–0.22)	7 (0–25)	18 (0–48)	4 (3–5)	7 (5–10)
Stress fracture	8	7	0.04 (0.02–0.07)	0.04 (0.02–0.08)	60 (23–96)	71 (0–143)	2 (1–4)	3 (2–7)
Muscle injury	16	19	0.07 (0.04–0.12)	0.10 (0.06–0.15)	7 (0–32)	14 (6–22)	2 (1–2)	2 (1–2)
Ankle	66	40	0.30 (0.23–0.38)	0.21 (0.15–0.28)	14 (0–42)	12 (0–35)	13 (10–17)	8 (6–11)
Joint sprains	21	6	0.09 (0.06–0.14)	0.03 (0.01–0.07)	14 (0–38)	14 (0–58)	3 (2–5)	1 (1–3)
Synovitis, impingement, bursitis	20	14	0.09 (0.06–0.14)	0.07 (0.04–0.12)	22 (0–85)	10 (0–46)	5 (3–8)	3 (2–4)
Tendon injury	19	14	0.09 (0.05–0.13)	0.07 (0.04–0.12)	7 (0–43)	11 (0–36)	3 (2–5)	2 (1–3)
Foot	50	39	0.22 (0.17–0.30)	0.20 (0.15–0.27)	16 (0–34)	16 (0–45)	8 (6–11)	9 (7–13)
Stress fracture	13	9	0.06 (0.03–0.10)	0.05 (0.02–0.09)	46 (16–76)	46 (0–110)	3 (2–5)	3 (2–7)
Joint sprains	19	8	0.09 (0.05–0.13)	0.04 (0.02–0.08)	14 (1–27)	27 (5–49)	2 (1–3)	1 (1–3)

Supplementary Table 2 Number and percentage of medical attention and time-loss injuries by classification, occurrence, and nature (95% confidence intervals).

	Medical Attention Injury				**Time-Loss Injury**			
	***n* injuries**		**Percentage**		***n* injuries**		**Percentage**	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
Classification								
Overuse	637	434	68.9 (65.9–71.8)	64.7 (61.1–68.3)	151	125	50.3 (44.7–56.0)	51.4 (45.2–57.7)
Traumatic	223	185	24.1 (21.4–26.9)	27.6 (24.2–31.0)	121	99	40.3 (34.8–45.9)	40.7 (34.6–46.9)
Not classified	65	52	7.0 (5.4–8.7)	7.7 (5.7–9.8)	28	19	9.3 (6.0–12.6)	7.8 (4.4–11.2)
Occurrence								
First episode	597	427	64.5 (61.5–67.6)	63.6 (60.0–67.3)	213	162	71.0 (65.9–76.1)	66.7 (60.7–72.6)
Recurrence	321	237	34.7 (31.6–37.8)	35.3 (31.7–38.9)	85	79	28.3 (23.2–33.4)	32.5 (26.6–38.4)
Not classified	7	7	0.8 (0.2–1.3)	1.0 (0.3–1.8)	2	2	0.7 (0.0–1.6)	0.8 (0.0–2.0)
Nature								
Extrinsic	249	174	26.9 (24.1–29.8)	25.9 (22.6–29.2)	99	80	33.0 (27.7–38.3)	32.9 (27.0–38.8)
Intrinsic	670	493	72.4 (69.6–75.3)	73.5 (70.1–76.8)	199	162	66.3 (61.0–71.7)	66.7 (60.7–72.6)
Not classified	6	4	0.6 (0.1–1.2)	0.6 (0.0–1.2)	2	1	0.7 (0.0–1.6)	0.4 (0.0–1.2)

Supplementary Table 3 Number and percentage of medical attention and time-loss injuries by injury mechanism, activity, and footwear (95% confidence intervals).

	Medical Attention Injury				**Time-Loss Injuries**			
	***n* injuries**		**Percentage**		***n* injuries**		**Percentage**	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
Mechanism								
Jumping/landing	200	206	21.6 (19.0–24.3)	30.7 (27.2–34.2)	81	92	27.0 (22.0–32.0)	37.9 (31.8–44.0)
Pointe	132	3	14.3 (12.0–16.5)	0.4 (0.0–1.0)	37	0	12.3 (8.6–16.1)	0.0 (0.0–0.0)
Plié/relevé	66	64	7.1 (5.5–8.8)	9.5 (7.3–11.8)	21	21	7.0 (4.1–9.9)	8.6 (5.1–12.2)
Lifting/lifted	31	98	3.4 (2.2–4.5)	14.6 (11.9–17.3)	11	29	3.7 (1.5–5.8)	11.9 (7.9–16.0)
Arabesque	65	20	7.0 (5.4–8.7)	3.0 (1.7–4.3)	15	7	5.0 (2.5–7.5)	2.9 (0.8–5.0)
Pirouette	11	20	1.2 (0.5–1.9)	3.0 (1.7–4.3)	2	8	0.7 (0.0–1.6)	3.3 (1.0–5.5)
Non-dance related	60	36	6.5 (4.9–8.1)	5.4 (3.7–7.1)	25	14	8.3 (5.2–11.5)	5.8 (2.8–8.7)
Cannot recall	89	60	9.6 (7.7–11.5)	8.9 (6.8–11.1)	33	18	11.0 (7.5–14.5)	7.4 (4.1–10.7)
Not classified	271	164	29.3 (26.4–32.2)	24.4 (21.2–27.7)	75	54	25.0 (20.1–29.9)	22.2 (17.0–27.4)
Activity								
Rehearsal	478	307	51.7 (48.5–54.9)	45.8 (42.0–49.5)	149	100	49.7 (44.0–55.3)	41.2 (35.0–47.3)
Performance	206	110	22.3 (19.6–25.0)	16.4 (13.6–19.2)	66	45	22.0 (17.3–26.7)	18.5 (13.6–23.4)
Class	104	140	11.2 (9.2–13.3)	20.9 (17.8–23.9)	34	49	11.3 (7.7–14.9)	20.2 (15.1–25.2)
Gym	8	21	0.9 (0.3–1.5)	3.1 (1.8–4.4)	1	7	0.3 (0.0–1.0)	2.9 (0.8–5.0)
Pilates/Gyrotonics®	3	1	0.3 (0.0–0.7)	0.1 (0.0–0.4)	1	0	0.3 (0.0–1.0)	0.0 (0.0–0.0)
Rehab	-	3	-	0.4 (0.0–1.0)	-	2	-	0.8 (0.0–2.0)
Non-dance related	56	39	6.1 (4.5–7.6)	5.8 (4.0–7.6)	25	20	8.3 (5.2–11.5)	8.2 (4.8–11.7)
Not classified	70	50	7.6 (5.9–9.3)	7.5 (5.5–9.4)	24	20	8.0 (4.9–11.1)	8.2 (4.8–11.7)
Footwear								
Ballet Flats	106	533	11.5 (9.4–13.5)	79.4 (76.4–82.5)	34	187	11.3 (7.7–14.9)	77.0 (71.7–82.2)
Pointe Shoes	658	7	71.1 (68.2–74.1)	1.0 (0.3–1.8)	210	2	70.0 (64.8–75.2)	0.8 (0.0–2.0)
Character Shoes	30	22	3.2 (2.1–4.4)	3.3 (1.9–4.6)	9	10	3.0 (1.1–4.9)	4.1 (1.6–6.6)
Barefoot	8	9	0.9 (0.3–1.5)	1.3 (0.5–2.2)	3	5	1.0 (0.0–2.1)	2.1 (0.3–3.8)
Trainers	20	22	2.2 (1.2–3.1)	3.3 (1.9–4.6)	6	7	2.0 (0.4–3.6)	2.9 (0.8–5.0)
Not classified	103	78	11.1 (9.1–13.2)	11.6 (9.2–14.0)	38	32	12.7 (8.9–16.4)	13.2 (8.9–17.4)

DISCUSSION

This is the first study to report longitudinal medical attention incidence rates in professional ballet. Differences in medical attention incidence rates were observed across company rank, with First Soloists and Principals demonstrating an almost two-fold greater incidence rate compared to Apprentices. The time-loss injury incidence rate observed in this study is in line with published literature,[1–5] however, the severity of time-loss injures was greater, with 35% of injuries resulting in more than 28 days of modified dance activity.[1,4] Consistent with previous research in professional ballet, most time-loss injuries were classified as overuse.[1–3] The most common mechanism of time-loss injury was jumping and landing activities, however, a similar number of injuries did not have a clear mechanism of injury.

Incidence Rate

No studies in professional ballet have previously reported medical attention injury incidence rates, however, the values observed in the present study are similar to those seen in professional contemporary dance.[23] The incidence rate of time-loss injuries in this study falls within ranges that are reported in professional ballet,[1–3,5] is comparable to cricket[24] and contemporary dance,[23] greater than that of modern dance,[25,26] but lower than rugby union or ice hockey.[27,28] In the absence of a direct comparison of activity profiles across dance genres, it is speculative to discuss differences in incidence rates between them. While time-motion analysis has revealed reduced activity demands in contemporary dance compared to ballet,[29] no such comparisons have been made between modern dance and ballet. Compared to invasion sports, however, the lower incidence rates observed in the present study may be due to fewer traumatic contact events during dance performance versus match play; incidence rates during rugby training, for example, are similar to those observed in the present study.[30]

First Soloists and Principals sustained between 2.0–2.2 additional medical attention injuries per 1000 hours and 0.9–1.1 additional time-loss injuries per 1000 hours compared to

Apprentices. The transition period from pre-professional training into a professional ballet company has been previously identified as a potential risk factor for injury.[31] Our findings, however, demonstrate that Apprentices are at the lowest risk of injury compared to other company members. It is plausible that Apprentices may avoid disclosing injuries when trying to establish themselves within a new company. However, injury incidence rates are likely higher in senior ranking dancers due to the casting of more technically and physically demanding roles within these ranks compared to junior dancers.[14,32] The casting of roles and distribution of workload across company ranks is, however, at the discretion of the Artistic Director, and the utilisation of junior dancers may differ across ballet companies.

Between 2.0–2.8 additional medical attention injuries per 1000 hours were observed at the start (August and September) and end (June) of the season compared to mid-season. Higher medical attention injury incidence rates at the start of a season may suggest strategies are warranted for returning dancers, such as pre-season training or a more gradual reintroduction to ballet. The higher incidence rates observed at the end of the season may be influenced by dancers who have been managing medical issues during the season.[15] However, it should be noted that mixed bill productions, which demonstrate an additional 2.3 medical attention injuries and 0.8 and time-loss injuries per 1000 hours compared to full-length stand-alone productions, are more common later in the season. While inter-season differences in medical attention injury incidence rates were seen, no clear pattern was observed across the five seasons, potentially due to inter-season variation in repertoire. Understanding the incidence rates associated with production types may be beneficial to Artistic Directors and medical staff when planning and periodising a season.

Severity

The severity of time-loss injuries within the present study is almost two-fold greater than the severity previously published in professional ballet,[1] similar to football,[33] and lower than rugby union,[28,30] and volleyball.[34] Professional ballet has previously been described as a culture that normalises pain,[15,35,36] which may result in dancers not reporting medical issues and dancing through discomfort. We observed that 56% of all days lost to time-loss injury were classified as ‘restricted’ as opposed to ‘off’, suggesting that dancers may still have been participating in some form of dance activity while injured.

Time-Loss Injury Aetiology

Between 65–69% of medical attention and 50–51% of time-loss injuries were insidious and a consequence of overuse. The greater proportion of overuse injuries observed under the medical attention definition suggests that overuse injuries may be underestimated using a time-loss injury definition alone.[37] Previous studies in professional ballet have reported that a high proportion of time-loss injuries were overuse;[1,3] our results align with this, although it should be noted that inter-season variation was observed. The high frequency of overuse injuries observed may also be associated with the large exposure times; the scheduled exposure hours in professional dance is greater than that reported in sport.[14,25,34] The primary mechanism of time-loss injury was jumping and landing, in line with previous research.[1] We also observed a greater percentage of time-loss injuries associated with jumping and landing in male dancers compared to females, however, the absolute number of injuries attributed to this mechanism was similar across sexes. In contrast to sport, where injuries principally occur in competition,[27,28,33] more than two-thirds of all time-loss injuries observed in the present study were attributed to training as opposed to performance. The higher proportion of training-related injuries is likely due to the 3.5 fold greater exposure hours observed during class and rehearsal compared to performance. Most injuries were classified as first episodes rather than recurrences, suggesting that time-loss injury rehabilitation is largely successful. The majority of injuries were classified as intrinsic, and may therefore provide an opportunity for training interventions or appropriate load management.[38–41]

Anatomical Region and Tissue Type

Previous research in professional ballet has reported injury region and tissue type inconsistently, making comparison with these studies challenging.[1,3–5] Generally, injuries to the distal lower extremity and joint/ligament tissue types demonstrated the greatest burden across all dancers. Ankle injuries pertaining to synovitis, impingement, and bursitis exhibited the greatest burden in female dancers, however, tendon and joint pathologies of the ankle were similar. *Pointe* positions, typically adopted by female dancers, require extreme range of motion of the ankle and may have negative consequences for musculoskeletal joint health. In male dancers, stress fractures to the foot and lower leg demonstrated the greatest burden. Nineteen of the twenty-one stress fractures recorded in males were attributed to jumping and landing activities and eighteen were non-traumatic. Medical management strategies addressing the joint and ligament injuries to the ankle in females and stress fractures to the foot and lower leg in males are warranted in this population.[43]

Strengths and Limitations

The strengths of this study include the prospective data entry from Chartered Physiotherapists, use of individualised prospectively entered dance exposure data, reporting of data through standardised entry forms, duration of data collection, consistency of the observed cohort, and the elite performance standard of the observed cohort.

Several limitations should be noted. Performance exposure was potentially inflated where individuals were allotted the total duration of a performance rather than on-stage time. Further, no register of attendance was taken for class or rehearsal, with attendance assumed but not verified. The authors, however, believe that it would be unusual for dancers to not attend scheduled dance events.

Multiple Chartered Physiotherapists were employed over the study period which may affect the uniformity of how injury data were gathered. It should be emphasised, however, that all physiotherapists used the same standardised entry forms and classification tools. The high frequency of overuse injuries may result in the misclassification of injury mechanism due to no traumatic inciting event.[13] Data describing injury region and tissue type were only presented for time-loss injuries, which may not represent all medical attention injuries. Four injuries were rehabilitating at the point of analysis and were subsequently removed from severity calculations. Finally, one ballet company was investigated and, thus, caution should be taken when generalising findings to other companies based on the season structure, hierarchy of company ranks, and casting of featured roles across company ranks.

Conclusion

This is the first prospective cohort study to investigate the longitudinal medical attention and time-loss injury incidence rates in a professional ballet company. First Soloists and Principals experienced medical attention and time-loss injury incidence rates roughly two-fold that of Apprentices. Although no differences in intra-season time-loss injury incidence rates were observed, 2.0–2.8 additional medical attentional injuries per 1000 hours were recorded at the beginning and end of the season compared to mid-season. The majority of injuries were overuse in nature and ~60% of all injuries occurred during training (rehearsal and class) compared to performance. The most common mechanism of time-loss injury was jumping and landing actions, however, many injuries were unclassified. Lower extremity injuries and injuries pertaining to joint and ligament tissue types caused the greatest burden. The results of this study may inform the design of targeted injury prevention interventions focusing on senior company ranks, intra-season variation, and jumping and landing activities in professional ballet dancers.

DISCLOSURE

Competing Interests None of the authors has any conflicts of interest to declare.

Contributorship GR implemented the electronic data management system. All authors contributed to the conception and design of the work. AM, JS, and SW completed the data analysis. AM wrote the first draft and prepared all revisions. All authors reviewed and edited drafts, and approved the final manuscript.

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Data Sharing No data are available

Patient Involvement There was no patient or public involvement in this study

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